Global gas prices are set to rebound

A glut of liquefied nat- ural gas that has sent global prices toward historic lows could be erased as soon as a year from now, accord- ing to Charif Souki, co-founder of LNG- terminal developer Tellurian Inc, reports Bloomberg. While gas prices are too low across the globe to justify build- ing new export termi- nals, more facilities are needed to meet rising demand, according to Souki. Given building terminals takes a long time, and limited new capacity is slated to come online in the next five years, LNG prices may be set for a rebound, he said. “They cannot crash any more than they already have,” Souki said in an interview last week, referring to LNG prices. “You cannot justify building anything at these current levels, it’s not sustainable. We are go- ing to be short of LNG” in the next 12 months, he said. Several new projects were greenlit last year.

Oil Off To Slowest Start Since 1991 With Virus Fear Spreading

Oil is off to the worst begin to a yr since 1991, tumbling 16% in January on concern that the unfold of coronavirus will curb demand for transportation fuels.

Futures fell 1.1% in New York on Friday, capping the worst month since May as traders have been rattled by the concern of demand destruction after the World Health Organization declared the outbreak a world well being emergency. The U.S. Centers for Disease Control and Prevention referred to as the virus an unprecedented public well being risk.

“People are wanting on the continued rise in circumstances and the way that’s impacting jet gasoline and has made these

demand fears worse," Leo Mariani, vitality analyst at KeyBanc Capital Markets Inc. "It's going to take the virus not being a persistent occasion and for international demand to indicate indicators of enchancment so as to stabilize."

China, the world's second largest financial system and key driver of oil demand, resorted to unprecedented measures to sluggish the outbreak, together with extending the Lunar New Year vacation and a lock-down within the nation's main cities and provinces. At least two-thirds of China's financial system will keep shut subsequent week, as residents are being advised to not return to work or college, or to keep away from congregating in public locations.

The plunge in oil costs has prompted a push led by Saudi Arabia for the Organization of Petroleum Exporting Countries and its allies to carry an emergency session in February, with Russia signaling for the primary time on Friday it was open to holding the assembly earlier.

The coalition is contemplating a proposal to deepen present manufacturing curbs by about 500,000 barrels a day, although there's no consensus on the concept but, in keeping with marketing consultant Energy Aspects Ltd. As the oil producer group and its companions, a 23-nation coalition referred to as OPEC+, have already made steep cutbacks not too long ago, analysts have been skeptical on how far more they're keen to do.

"This virus is requiring extra out of the group because the demand image will get weaker," mentioned Rebecca Babin, a senior fairness dealer at CIBC Private Wealth Management.

West Texas Intermediate crude for March supply fell 58 cents to settle at $51.56 a barrel on the New York Mercantile Exchange, after sliding as a lot as 2.2% throughout the session.

Brent for March supply, which expired Friday, misplaced 13

cents to $58.16 a barrel on the London-based ICE Futures Europe change, and sank 12% in January. The extra lively April contract slid 71 cents to $56.62 a barrel. April Brent was $four.94 a barrel above WTI for a similar month.

In addition to the drop in outright costs, the market's construction confirmed additional indicators of the market malaise. April Brent's premium over May contracts falling by about greater than one-third to simply 20 cents a barrel. The December 2020-December 2021 unfold, a intently watched indicator of the market's power, shrank 70 cents a barrel, the bottom because the finish of October. On Jan. 6, it closed at $four.05.

Opec's January oil output plunges on new cuts and Libyan unrest

LONDON (Reuters) – OPEC oil output plunged in January to a multi-year low as top exporter Saudi Arabia and other Gulf members overdelivered on a new production-limiting accord and Libyan supply dropped due to a blockade of ports and oilfields, a Reuters survey found.

On average, the 13-member Organization of the Petroleum Exporting Countries pumped 28.35 million barrels per day (bpd) this month, according to the survey. That is down 640,000 bpd from December's revised figure.

Despite the drop in supply, crude prices have slipped to below $60 a barrel on concern that the coronavirus outbreak could cut China's oil demand. This has prompted OPEC and its allies to discuss holding an early meeting and taking further steps to support the market.

OPEC, Russia and other allies, known as OPEC+, agreed to deepen an existing supply cut by 500,000 bpd from Jan. 1 2020. OPEC's share of the new reduction is about 1.17 million bpd, to be made by 10 members, all except Iran, Libya and Venezuela.

The 10 OPEC members bound by the agreement easily exceeded the pledged cuts in January thanks to Saudi Arabia and its Gulf allies cutting more than called for to support the market.

OPEC complied with 133% of the pledged cuts in January, the survey found. In December, the group implemented 158% of the promised curbs.

January's output was the lowest by OPEC since 2009, the year in which the group implemented its biggest-ever supply cut due to the financial crisis, excluding membership changes that have taken place since then, according to Reuters surveys.

LIBYAN PLUNGE

Oil output in Libya has plunged since Jan. 18 due to a blockade of ports and fields by groups loyal to eastern-based commander Khalifa Haftar.

Production in Libya averaged 760,000 bpd during the month, the survey found, down from 1.15 million bpd in December.

Saudi Arabia trimmed supply from December's rate, voluntarily going beyond the reduction it is required to make under the OPEC+ accord. Gulf ally the United Arab Emirates also overdelivered, sources in the survey said.

The January survey suggests Nigeria and Iraq, both laggards in making cuts in 2019, achieved some progress. Both countries reduced output although they have more to do in later months.

Among countries pumping more, Venezuela, which is contending with U.S. sanctions imposed on state oil firm PDVSA and a long-term decline in output, managed a small boost to supply with exports increasing in January.

Production from the other exempt producer Iran, under U.S. sanctions, was steady.

Ecuador left OPEC at the end of 2019, lowering OPEC production by about 500,000 bpd. The country has been removed from December's total to compare more easily production by remaining members.
The Reuters survey aims to track supply to the market and is based on shipping data provided by external sources, Refinitiv Eikon flows data and information provided by sources at oil companies, OPEC and consultants.

Russia oil output rises as new Opec+ quota excludes condensate

Bloomberg/Moscow

Russia's oil production increased to a five-month high in January following an agreement with the Opec+ alliance to exclude condensate from its quota.

The nation pumped 47.72mn tonnes of crude and condensate — a light oil extracted from natural gas — last month, Interfax reported, citing preliminary data from the Energy Ministry's CDU-TEK unit. The figure, which may be rounded, equates to about 11.28mn barrels a day on average, based on the standard 7.33 barrels-per-tonne conversion ratio.

The CDU-TEK data usually doesn't provide a separate figure for crude production, so it can't be used to gauge Russia's compliance with promised output cuts. In December, the country successfully lobbied the Organisation of Petroleum Exporting Countries and its allies to exclude condensate from its quota. Energy Minister Alexander Novak has insisted the exclusion isn't a loophole, and that Russia will be transparent about its oil production. Last month, the ministry published December figures that showed how Russia may disclose its compliance. While the statement was less detailed than the CDU-TEK data, it split output cuts into crude and condensate, compared with the respective October 2018 baselines.

Russia has pledged to cut its crude-only output by 298,000 barrels a day this quarter, from a baseline of 10.626mn barrels a day. The nation was not far from meeting that target in December, the Energy Ministry said, reporting crude-only cuts of 234,000 barrels a day.

Russia largely failed to meet its obligations in 2019 under the previous Opec+ deal. It attributed that failure to challenging weather and geological conditions in winter, the temporary shutdown of the Druzhba oil pipeline and growing condensate output at gas projects. Russia's main gas producers Novatek PJSC and Gazprom PJSC have been bringing new fields online and expanding existing projects to ramp up exports to markets in Europe and Asia.

Qatargas delivers ‘commissioning LNG cargo’ to India’s newest Mundra terminal

Qatargas has supplied a commissioning liquefied natural gas (LNG) cargo for India’s newest LNG receiving terminal – Mundra, located on the west coast of India.

The cargo was loaded in Ras Laffan on January 17 on the Q-Flex LNG vessel, Murwab, with an overall cargo carrying capacity of 216,000 cubic metres. It arrived at Mundra terminal on January 22.

Mundra is the second LNG terminal that Qatargas helped commission in India within the past year. It followed an earlier commissioning cargo, which was delivered by the company to the Ennore LNG receiving terminal, near the southern Indian city of Chennai, in February 2019.

The Mundra terminal is located in Adani Ports and Special Economic zone in Kutch district of the western Indian state of Gujarat.

The terminal’s nominal capacity is 5mn tonnes of LNG per year (mtpy), and it can receive vessels with a capacity between 75,000 cubic metres and 260,000 cubic metres. The terminal

comprises of two storage tanks – each with an overall capacity of 160,000 cubic metres.

Qatargas has established a strong partnership with India since July 1999 when it started supplying LNG to Petronet. Since then it has delivered more than 2,000 cargoes under its various long-term sales and purchase agreements as well as supplying significant volumes into the short term and spot markets.

India is a key market for Qatargas given its geographical proximity and growth potential. Upcoming developments such as new terminals and other gas related infrastructure will increase India's capacity to import LNG from 30mn tpy to 44mn tpy, a 46% increase as India continues to make strides in achieving its ambitious target of 15% gas in the energy mix.

What the ECB's Strategy Review Must Do

he European Central Bank’s new strategy review must recognize that economists are still a long way from understanding the dynamics of low inflation. Given this uncertainty, the ECB should aim to adopt robust policies that cause the least damage under a broad range of scenarios.

LONDON – With her recent announcement of the European Central Bank’s long-overdue strategy review, new ECB President Christine Lagarde has generated high expectations. The review’s outcome will be the first important signal of how Lagarde intends to lead the institution – and of how the ECB is likely to address persistently low inflation in the eurozone.

The world is very different than it was in 2003, when the ECB’s strategy was last revised, and the institution has itself undergone deep changes since the 2008 financial crisis. Faced with a global recession and then the 2011-2012 eurozone debt crisis, the ECB abandoned the traditional approach of passively meeting banks’ demand for liquidity – its initial response to the financial crisis. Instead, the ECB started actively managing its balance sheet in order both to ease monetary policy and stabilize the financial system.

Furthermore, the ECB has radically expanded its operational tools. In 2014, it introduced negative interest rates on banks’ deposits with national central banks, and began providing the market with “forward guidance” concerning its future policies. And, since 2015, the ECB has engaged in asset purchases (known as quantitative easing, or QE), causing its balance sheet to double compared to 2008. Finally, the ECB has assumed larger prudential supervisory responsibilities *vis-à-vis* European banks under the Single Supervisory Mechanism.

The first phase of the ECB review will be narrow, focusing on defining the bank’s inflation target, the role of monetary aggregates as signals of medium- to long-term inflation, and communication. This is expected to be concluded in the first

half of 2020, to be followed by a second phase of reflection.

Any meaningful review of these issues must objectively and critically analyze the decade since the financial crisis, during which average eurozone inflation has been well below the ECB's objective of "below, but close to, 2%," and also lower than in the United States and the United Kingdom. In particular, the review should quantify the costs of tolerating a systematically below-target level of inflation, relative to pursuing other policy options.

There are at least three hypotheses to explain the ECB's inability to achieve its inflation objective. The "policy mistakes" hypothesis maintains that the ECB should have implemented more aggressive policies – in particular, QE – between 2012 and 2014. If these "mistakes" stemmed from an ill-defined ECB strategy, then its strategy will have to be adjusted; if they were the result of political constraints, then its decision-making process should be changed.

The second explanation highlights the inadequate coordination of fiscal, financial, and monetary policy in the eurozone. In 2009, for example, monetary easing was accompanied by a delayed cleanup of the banking sector and fiscal austerity, leading to a second recession that the ECB was late to identify. And in 2012-2014, a neutral fiscal stance was coupled with both insufficient monetary stimulus and banking-sector deleveraging.

Both hypotheses suggest that the ECB would have fared better had it clearly committed to a symmetric quantitative target for inflation or nominal GDP. That would have implied, for example, not increasing interest rates in 2011 (as the ECB did) in response to the temporary inflationary effect of higher oil prices. It also would have implied starting asset purchases in 2012 instead of 2015, and not stopping them in 2018.

The third hypothesis, favored by some central bankers, is that persistently low eurozone inflation reflects structural factors such as adverse demographics, low growth expectations, and the associated increase in demand for safe assets. This explanation thus draws parallels between the eurozone and Japan, where aggressive monetary and fiscal policies since 2013 have failed to lift the economy out of its two-decade-long slough of low inflation.

Advocates of the structural view argue that it would be better for the ECB's policymakers to adopt a lower inflation target rather than try to engineer a monetary stimulus that ends up inflating asset prices and jeopardizing financial stability. After all, their argument implies, there is little evidence that stable low inflation is bad for welfare.

But this third hypothesis can lead to two alternative policy recommendations. The first is a "do-nothing" approach, coupled with a downward adjustment of the ECB's inflation target in line with actual inflation. Such a course of action is justified if policymakers assume that potential output growth in the eurozone has declined independently of past fiscal and monetary stabilization policies. The second option, as under the first two hypotheses, is to maintain an accommodative monetary policy, possibly in coordination with fiscal policy. This would be the right thing to do if policymakers believed that persistent slack in the real economy would end up affecting potential output.

Most analyses imply that ECB policy has in general been too cautious during the last decade. Moreover, even if one accepts the structural explanation for trend inflation and takes the view that inflation expectations have fallen independently of past policies, the "do-nothing" option is likely to cause expectations to spiral further downward, possibly leading to a deflationary trap. One then has to consider the costs linked both to the associated relative price adjustments and to the effect that the resulting upward pressure on the real interest

rate would have on the burden of private and public debt. These costs are likely to be greater than those associated with the financial-stability risk of doing “too much,” which in any case can be addressed using prudential tools.

The ECB’s new strategy will have to be based on the kind of quantitative analysis needed to answer these questions. But it also must recognize that economists are still a long way from understanding the dynamics of low inflation. Given this uncertainty, the ECB should aim to adopt robust policies that cause the least damage under a broad range of scenarios.

Outgoing BP CEO warns of moving too fast on climate change

BP Plc’s outgoing Chief Executive Officer Bob Dudley warned Big Oil of moving too fast on investing in new technologies to counter climate change, because their failure could lead to financial ruin.

“If you go too fast and you don’t get it right you can drive yourself out of business,” Dudley said in a Columbia Energy Exchange podcast with Professor Jason Bordoff.

Oil companies must retain a strong financial footing to be able to invest when game-changing technologies are developed, he said. In the early 2000s, before his tenure as CEO, BP invested heavily in solar technology only to write off much of the spending.

“If we understand where the technologies are going and we invest, the best thing we can do strategically is have a strong balance sheet. When it becomes really clear certain technologies are going to move very quickly and be profitable, then we’ll be able to make that shift.”

Here are other select quotes from the interview:

On Big Oil’s role in the energy transition:

BP, Exxon Mobil Corp., Royal Dutch Shell Plc, Chevron Corp and Total SA are “only responsible for producing about 8% of the world’s oil. If we were all driven out of business that oil would still be produced” by national oil companies and other countries.

“We want to be leaders in this and we do enormous amount as companies” such as in developing technology and reducing emissions from their own operations. But “we’re not the epicenter of these issues.”

On BP’s dividend:

“I meet with shareholders and they say ‘we would like you to move really quickly into renewables.’ I say, ‘we can do that, would you like us to cut the dividend?’ They go, ‘no, no, don’t do that.’ We’ve got to find the right balance and pace here.”

Green deal law to make EU’s energy shift irreversible

Bloomberg/Brussels

Europe wants to make its goal of becoming the first climate-neutral continent irreversible under a new law that is to be unveiled next month, offering investors the certainty they ask for before backing unprecedented levels of investment.

The climate law will require all corners of the economy to take action and give the institutions co-ordinating the shift the legal authority to act when the promises to deliver are broken, according to Frans Timmermans, executive vice-president of the commission.

“This is an exercise in disciplining this transformational age,” Timmermans told a conference in Brussels yesterday. “Transforming a society that is entirely based on carbon to a society that no longer needs carbon as a fundamental basis for its functioning is of a tectonic nature.”

The remarks are meant to build support for the package due on February 26 and to give groups with a stake in the issue a sense of the scale of the project.

The industry is already working on technologies such as carbon capture and storage or hydrogen, and for companies it’s no longer a question of climate targets but of how to ensure the necessary funds for the unprecedented overhaul, according to

Marco Mensink, director general of the chemical industry association Cefic.

“I’ve been in Brussels for 15 years now, and I think that people in the room agree we’ve never been in as an exciting moment as we are right now,” Mensink told the conference on the climate law. “That is a 1tn euro or more market opportunity if we get it right; it’s also an enormous investment that has to come to Europe.”

The measures would enshrine in law the Green Deal, a far-reaching strategy to eliminate greenhouse gas emissions by the middle of the century. The shift is at the heart of the agenda of European Commission President Ursula von der Leyen and will affect areas from energy production to transport and agriculture.

The deal is aimed at putting Europe in sync with the objectives of the Paris Agreement on climate change. It would also entrench Europe’s leadership on the environment, putting it ahead of major polluters including China, India and Japan, which have yet to translate their voluntary Paris pledges into binding national measures. US President Donald Trump wants to withdraw from the Paris Agreement.

“This is an epic challenge,” Timmermans said. “It’s also an incredible opportunity for Europe to lead. If we get it right, I can assure you that worldwide there will be huge interest in studying our idea for the climate law. I get questions about this from all parts of the world.”

The climate law requires support from member states and the European Parliament. It will make the 2050 climate neutrality goal binding and may include hints on the trajectory for the bloc to get to zero net emissions.

Von der Leyen signalled she wanted to toughen the 2030 emission-reduction goal to 50% or even 55%. The target is currently to cut pollution by at least 40%.

The commission is likely to stop short of proposing a new target for 2030 at this stage, waiting with more details until the second half of this year when it’s due to publish an analysis on tougher climate goals. That’s set to create

friction with the European Parliament, which is adamant that the new law include a 55% reduction target for 2030.
Legislative work on the new climate law is set to last several months. Croatia, which is chairing meetings of member states in the first half of 2020, wants national governments to agree on their common negotiating position in June.
The European Parliament's environment committee may approve a stance on the law in June, its chairman Pascal Canfin told the conference yesterday. The committee's decision could be followed by a plenary vote in mid-July, he said. Only then can the two institutions start discussions about the final shape of the law.
While Europe is ready to bet its future on the environmental clean-up, the costs of the transition are dizzying. Reaching the existing climate targets will require additional spending of €260bn ($286bn) annually, according to commission estimates. The commission earlier this month unveiled a sustainable investment plan to help mobilise at least 1tn euro over the next decade to help the green shift.

Tears flow as politicians fail to dispel 'climate darkness'

Standing before a captive audience at this month's climate change conference in Madrid after entertaining them with a dance in her traditional Pacific island costume, 21-year-old Tabita Kaitamakin Awira Awerika's smile turned to angry tears.

The student from Kiribati spoke of her anguish at the threat to her low-lying atoll nation from rising sea levels and ferocious storms – and the determination of her people not to let global warming chase them from their "beloved motherland".

"I am very sad to say that as the youth of many developed nations are enjoying their daily activities, our fellow youth in Kiribati are worrying about what the future holds for us," she told an event on the sidelines of the UN talks.

"My leaders have voiced these concerns to the global community over and over but no one is listening – are we that insignificant for our cries to fall on deaf ears?"

Emotional exhortations like this are being heard more often at the annual climate summit, especially from young people, as climate change fuels extreme weather, glaciers melt, and the world's oceans creep inexorably higher.

In Madrid, veterans of the "COP" meetings – known as a place where suited officials spar over complex agreements – said they had never seen such an outpouring of grief, anxiety and sorrow.

Bill Hare, founder of climate science think-tank Climate Analytics, told US news show “Democracy Now!” he had seen more tears in Madrid than at the previous 24 summits, dubbing it “the crying COP”.

Representatives of small island states were “almost panicking” at the prospect of their homelands disappearing under the waves, while young people were “angry and upset” at a lack of action by politicians, he said.

During two fractious weeks of talks, a handful of major polluting states resisted pressure to ramp up efforts to combat climate change, angering smaller countries and a growing protest movement that is pushing for emergency action.

The climate change talks have experienced a “big shift” away from formality in recent years, said Ashlee Cunsolo, director of the Newfoundland-based Labrador Institute of Memorial University and an expert on “ecological grief”.

Tuvalu negotiator Ian Fry grabbed the world’s attention at the 2009 Copenhagen talks by saying he had woken up crying, telling delegates tearfully, “the fate of my country rests in your hands”.

At the 2013 talks, Philippines negotiator Yeb Sano made headlines when he broke down speaking of the destruction wrought on his country by Typhoon Haiyan.

Cunsolo told the Thomson Reuters Foundation people were increasingly “refusing to separate science and feeling”.

“More and more, they are not embarrassed and not ashamed to share the emotions they are experiencing around these changes,” she said.

One key driver is rising exposure to climate and weather-linked disasters, whether Australia’s bushfires, flooding in the United States or Hurricane Dorian in the Bahamas, she added.

And then there are communities experiencing longer-term deterioration in their native environments, including Canada’s Inuit, who are struggling with losing the ice and what that means for their hunting-based lifestyle and food security.

“The lived experience that people have and are sharing

publicly on social media and in media articles has so far outstripped the research that we have," said the academic who co-authored a study on the subject, published in April 2018.

The paper identified "ecological grief" as "an underdeveloped area of inquiry" and warned it could "become more common as climate impacts worsen".

Yet while community groups have sprung up to help people cope with their feelings, and some health professionals are developing guidelines on mental health and climate change, efforts to quantify and tackle the phenomenon are lagging behind, Cunsolo and others said.

"If people don't hear about it, and don't talk about it, and it only grows within, then that is a recipe for disaster," said Pablo Suarez, associate director for research and innovation at the Red Cross Red Crescent Climate Centre.

At a parallel event in Madrid, he ran a workshop introducing development professionals to the concept of "climate darkness" – a term he prefers to "grief" which points to something that has already happened and is not a springboard for action, he said.

"A little bit of light can undo darkness," he said. "Emotional pain is a signal: these tough times are full of opportunities for heroic generosity and proactive humanitarian deeds."

As a global network of volunteers, the Red Cross is aware of the stress climate-related crises put on its humanitarian workers, as well as those directly affected, and plans to start providing better psychological support for them, Suarez said.

Cunsolo, meanwhile, said she and colleagues want to conduct a national survey across Canada next year, with a focus on vulnerable groups like farmers and indigenous people, with the aim of producing data that can be useful to decision makers.

In drought and fire-hit Australia, researchers are planning a similar effort, she noted.

Suarez, who has devised games and worked with cartoonists to help people understand climate risk, said one reason why major climate change events like the COP fell short of public

expectations was that they are “devoid of inspiration”.
“Why are COPs designed to discard the emotional richness needed to make us aim for more? Yes, climate negotiations are deadly serious, but they shouldn’t be deadly tedious,” he added, calling for an injection of art and humour.
In the absence of a collective push to act, however, the prospect of a ruined planet can lead to sadness and paralysis, he noted.
In Madrid, Marie Christina Kolo, a young eco-feminist from Madagascar, welled up as she spoke of village girls being pushed into early marriage because their parents could no longer earn enough from fishing in the African island nation’s warming seas.
“I hope (the negotiators) will not only consider data and percentages, but they will consider our lives,” she told journalists. – Thomson Reuters Foundation

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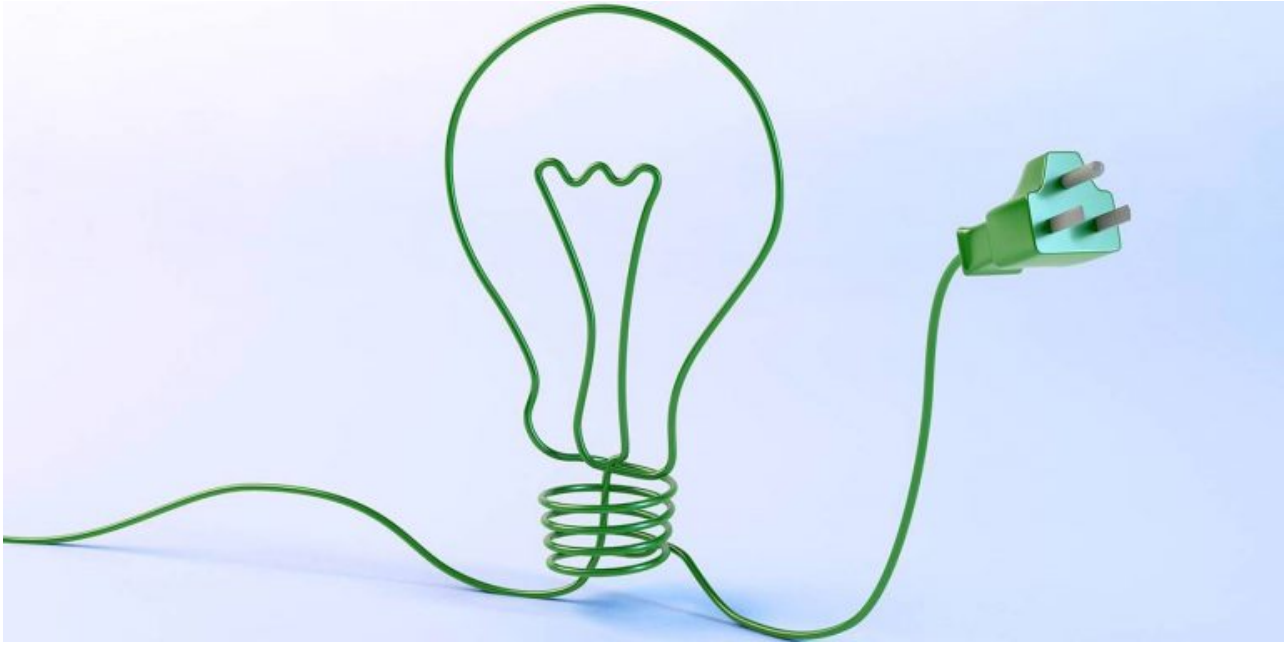
Winning the electrification race



If governments adopt bold policies to help accelerate the production of clean electricity, the world could build a zero-carbon economy fast enough to limit climate change to a manageable degree. But without such measures, a zero-carbon economy will come much too late.

LONDON – There is no doubt that by the year 2100, the world will enjoy abundant cheap zero-carbon energy. Coal will be confined to museums, and oil and gas use will be dramatically reduced. Technological progress makes that inevitable, even if unassisted by government policy. But to prevent potentially catastrophic climate change, a zero-carbon global economy must be achieved by mid-century. That, too, is possible, but only with strategic vision and strong policy support.

Electricity will dominate the future global energy system. Currently, it accounts for only 20% of final energy demand, with direct fossil-fuel use still dominant in transport, heating, and heavy industry. But most economic activities can be powered by electricity, and many will be far more efficient once electrified.

For example, internal-combustion engines typically turn 60-80% of all the energy they use into wasted heat, and only 20-40% into kinetic energy to drive the vehicle. Electric engines, by contrast, are over 90% efficient. Moreover, they are so much simpler to produce that within five years the cost savings on engines will offset the cost of batteries, making electric vehicles cheaper than diesel or gasoline cars. Similarly, electric heat pumps can deliver more than three kilowatt-hours of residential heating for only one kilowatt of energy input; no gas boiler could deliver more than 0.9 kWh for the same input.

Although battery-powered electric engines will play a growing role in short-distance aviation and shipping, batteries will be too heavy to power long-distance flights or intercontinental shipping for several decades yet. But ship

engines could burn ammonia rather than fuel oil – and ammonia can be a zero-carbon fuel if it is made from hydrogen produced by electrolyzing water, using electricity generated from renewable sources. In addition, synthetic jet fuel can be made from hydrogen and carbon dioxide extracted from the air. Hydrogen, whether used as a fuel or a key chemical input, will also play a major role in the decarbonization of heavy industrial sectors such as steel and chemicals.

Without assuming any fundamental technological breakthroughs, we could certainly build by 2050 a global economy in which electricity met 65-70% of final energy demand, and hydrogen, ammonia, or synthetic fuel met a further 12-15%. Bioenergy and fossil fuels would then need to meet only about 20% of total energy use – and applying carbon capture to this greatly reduced fossil-fuel use could then ensure a truly zero-carbon economy.

Moreover, such widespread electrification would deliver huge environmental benefits, eliminating the pollution, noise, and unwanted or wasted heat inevitably produced by burning fossil fuels in vehicles, gas boilers, and industrial processes.

Building this economy will require an annual global electricity supply of about 90,000 terawatt-hours, compared to 23,000 TWh today; all of that must be generated in a zero-carbon way. But this goal, too, is undoubtedly attainable. Every day, the sun radiates to earth enough energy to cover humans' daily energy needs 8,000 times, and we could provide 90,000 TWh of solar electricity using less than 1.5% of Earth's land surface (or less than 0.5% if its water surface could be used as well). Solar-energy costs have fallen by 85% in the last ten years, and in many locations solar power is already cheaper than coal; by mid-century, it will be cheaper still.

Wind-power costs also have declined fast, and nuclear fusion may be a commercially viable technology within two decades.

Battery costs have fallen by more than 80% since 2010 and will likely more than halve again by 2030, while a recent report suggests that electrolysis costs will now most probably "plummet." Furthermore, a wide array of other energy-storage and demand-management technologies promises to answer the key question for renewable power systems: what to do when the sun doesn't shine and the wind doesn't blow.

These developments make it inevitable that by 2100 the world will have an ample supply of cheap and totally clean energy. But it is not inevitable that we will avoid catastrophic climate change. Fossil-fuel use is still increasing, and global warming is currently on track to reach 3°C above pre-industrial levels by 2100, dramatically overshooting the target of well below 2°C set by the Paris climate agreement. And although solar and wind costs have plunged, we need to increase capacity at 3-4 times the current rate to have a feasible chance of producing 90,000 TWh of clean electricity by 2050.

The macroeconomic cost of such an effort is not at all daunting: the total incremental investment required to build a zero-carbon economy by 2050 amounts to about 1-1.5% of global GDP per year. But the required acceleration will not occur without forceful government policies.

Such policies must start by recognizing that massive clean electrification, plus large-scale hydrogen use, is the only route to zero-carbon prosperity. Governments should set challenging targets for increasing renewable (and in some cases nuclear) power capacity, while using auctions to secure private-sector delivery at the lowest possible cost. Road-transport strategies must aim to completely eliminate internal-combustion engines from our roads by 2050 at the very latest: this will require bans on the sale of new internal-combustion vehicles far sooner. In addition, carbon pricing is essential to make industrial decarbonization economic. Finally, governments must support new technologies with

initial deployment subsidies of the sort that have helped to reduce rapidly the costs of solar photovoltaic technology, wind turbines, and batteries.

With such policies, the world could build a zero-carbon economy fast enough to limit climate change to a manageable extent. But without the right measures, a zero-carbon economy will come much too late.